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EVOLUTION OF MODERN AVIATION AND EXPERIMENTAL AND TECHNICAL RESEARCHES IN AERODYNAMIC LABORATORIES.

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EVOLUTION OF MODERN AVIATION AND EXPERIMENTAL AND TECHNICAL RESEARCHES IN AERODYNAMIC LABORATORIES.*

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The art of constructing airplanes is now in full evolution, not to say revolution. This transformation is still proceeding slowly, but for many builders who have not hesitated to leave the beaten track, this slowness has been due to difficulties of a financial or material rather than of a technical order.

This evolution affects very different points, such as the general shape and dimensions of airplanes, the materials used in their construction, etc. These considerations are, moreover, mutually related. We know, in fact, that the exclusive use of metal depends on the size of the airplane and the shape of its wings.

We propose to examine here only one of the essential causes of this evolution, that arising from experimental researches and theoretical studies in aerodynamical laboratories.

Wings.

General Characteristics of Good Wing Sections.

Modern airplane wings have sections and shapes clearly deduced from the most recent discoveries of aerodynamics.

Let us first consider wing sections. A good wing section must offer the minimum parasite resistance and be capable of producing considerable lifting forces.

* Taken from "L'Aerophile," November 1-15, 1921.

The drag of a wing section generally comprises two parts:

1. The resistance due to the friction of the air on its whole surface;

2. The resistance due to impact and to the separation of air from wing, with the consequent parasitic vortices.

The drag of good modern wing sections is reduced almost entirely to the first kind of resistance, that is, to friction. This constitutes a considerable degree of progress, which the laboratories have been able to put into effect, as a result of improvements in their equipment. Hence the contour of these wing sections is such that the molecules of air encountered by the wing follow its surface, without impact or separation. The air "acts" perfectly on these wing sections, like fluids on the blade of a turbine. Of course this maximum improvement only covers the range of the angles of attack employed in aviation, which, however, already constitutes quite an extensive domain. The impact and separation of the air streams are always experienced, even on very good wing sections, whenever the angle of attack is very much above or below its normal range.

It is well to note that a long series of these good wing sections has been designed in accordance with the theory of the motion of perfect fluids. This had previously been determined for the best shapes of airships and streamlined rounded bodies.

<u>Drag Due to the Friction of the Air.</u>

The friction of the air on the wings is not a negligible

quantity. Many experimenters have determined its laws of variation with the speed and surface areas. We thus find that the friction does not increase exactly as the square of the velocity nor as the area of the surface. This means that the friction on one square meter of surface will be just so much less, for a given speed, as the square meter under consideration forms part of a larger surface. In the same way, equal speed accelerations do not correspond to equal increments of friction.

The laws of friction, of the air on plane surfaces, are well known and can be applied with just so much closer approximation, as there is less separation of the fluid molecules from the modern contours. We accordingly find that one square meter of lifting surface on an airplane flying 100 m/sec (360 km/hr) would require about 8 HP to overcome friction alone, assuming the surface to be well polished. This figure might be doubled with a less perfect polish. For the airplane built only for speed, like those participating in the Deutsch contest, the lifting surface being 12.5 square meters, for example, the engine power absorbed by the friction on the wing alone would be about 100 HP. To this must be added the power absorbed by the friction of the air on the other parts of the airplane.

Accurate knowledge of the resistance due to the friction of the air, therefore, requires that the constructor varnish and polish, with the greatest care, all the exterior surfaces of his airplanes. We know, moreover, that another object of this varnishing

and "doping" is to shrink the fabric covering of the wings. With progress in construction, fabric need not be considered, but the wood or metal coverings replacing them must be carefully polished if there is to be an improvement over the small coefficients of friction of the varnished fabric surfaces now employed.

Of course, the amount of the power absorbed by friction is not so great in an airplane of medium speed (commercial), though the increased friction due to its larger dimensions partially offsets the diminution of friction due to lower speed.

Drag Due to Lift.

Unfortunately, the drag of a wing due to friction is not the only drag. There is also the drag due to the lift, required to offset the weight of the airplane. This has been found to be proportional to the square of the lift. The cost of the lift consequently increases very rapidly with the magnitude of the drag.

But the coefficient of proportionality, that is to say, the other factor which enters into the value of the drag due to the lift depends only on the shape and disposition of the airplane. It seems therefore that the coefficient could be made very small, if the means of construction at our disposal enable the realization of the best shapes and dispositions. Experience has, in fact, shown that increasing the aspect ratio and the gap is the proper means of diminishing the drag due to lift.

As a result of the experimental researches and theoretical studies in aerodynamic laboratories, the constructing engineer

can now determine in advance the advantages or disadvantages inherent in all the shapes and dispositions suggested to him by the requirements of construction. He can definitely determine whether he must employ a single wing (monoplane) or a biplane or multiplane cell and the best proportions to give them.

Fuselage, Tail Planes and Other Aiplane Parts.

The laws of the resistance of the air to the fuselage are likewise accurately determined experimentally. In truth, a fuselage should have the shape of a revolving solid with the least head resistance. We can determine in advance the correct outline followed by the fluid molecules in air without viscosity. For such an outline, especially applicable to airship hulls, the head resistance is almost entirely due to the friction of the air. The amount due to impact and separation of the fluid streams is very small on such hulls and frequently does not exceed one-third of the total drag.

But for airplane fuselages, the necessities of construction, conditions of inhabitability and equipment, and communication with other parts often necessitate modifications of the ideal outlines. Nevertheless, the practical fuselage forms are tested in aerodynamic laboratories, which determine all their characteristics and also the influence of the particular dispositions due to the equipment or to the communications with the other parts.

In the same way, the aerodynamic properties of the tail planes, taken singly or in conjunction with other parts, have been studied

experimentally in great detail.

The case is the same with resistances due to landing gears, external fittings, etc. For these parts in particular, the laboratory has shown that the values of the resistances measured on small models are rarely applicable to the full size. Fortunately, the experimental apparatus has been sufficiently improved to enable the direct testing of these parts in full size. It is the results of these measurements that the engineer must apply in his calculations.

Interaction of Airplane Parts.

By interaction is meant the reciprocal action of two or more parts of an airplane or other aircraft, a reciprocal action which modifies, to a greater or less degree, the aerodynamic properties of each part taken separately.

Certain of these interactions have been accurately determined and can be calculated in advance for various combinations of two parts. These include, for example, the interaction or gap resistance of two or more wings superposed in such manner as to form a biplane or multiplane cell.

The interactions of the wings and horizontal tail planes have likewise been determined by a very complete study of the magnitude and direction of the downwash behind a wing.

Other interactions are of a more complex nature and can only be determined experimentally in each particular case. Such are, for example, the reciprocal actions of the wings and fuselages,

exterior fittings, the ground, etc. Lastly, as we shall see further along, the propeller itself reacts on the various parts of the airplane.

The total drag of an airplane can therefore be calculated from the individual resistances and interactions.

Airplane Propeller.

Propellers have been the object of a considerable number of systematic experimental researches. It may be said that the constructing engineer can surely find in this accumulation of documents the most suitable propeller for solving his particular problem. Moreover, general rules have been established which still further extend the field of application of the experimental results.

Lastly, the interactions of two tandem propellers and those between one or two propellers and the wings and fuselages of an airplane have been determined experimentally. Rules have been enunciated which render it possible to establish with certainty the complex engine-propeller groups of certain types of giant airplanes. Numerous and varied data enable us to calculate the interaction of propeller and airplane.

Airplane in its Entirety, Evolution of Shapes.

Either by the sum of the individual resistances and interactions of its parts or by testing a small model, the aerodynamic properties of a complete airplane have been determined in aerodynamic laboratories.

The engineer accordingly has in hand all the data for calculating his airplane and for determining its performances, degree of stability, maneuverability, etc. He knows the aerodynamic price, that is to say, the share of the total drag borne by each part, and consequently the engine power required for predetermined performances.

Under these conditions, he can work out the structural details with more confidence. It must be noted that the study of peace-time airplanes and especially of large modern airplanes necessitates large expenditures. The construction, followed by final adjustments and trials, requires considerable capital. It is therefore important to leave nothing to chance and to prevent failure at any cost.

Knowledge of the aerodynamic characteristics of airplanes has drawn the attention of investigators to the great importance of parasite resistances and interactions between essential parts, namely, the wings and tail planes. One of the most marked improvements in modern airplanes consists in obtaining airplane forms for which these parasite resistances are zero or as nearly so as possible. By utilizing modern wing sections, which, aside from their aerodynamic qualities, have the advantage of being relatively thick, engineers have been enabled to place nearly all bracing, engines, etc., inside the wing, so that the airplane tends toward a flying wing, equipped with one or more fuselages for supporting the tail planes and landing gear.

One of the essential factors in modern progress and evolution of aviation evolves therefore from the experimental researches and theoretical investigations of aerodynamic laboratories.

Conclusion.

The technical data already obtained by the experimenters of the different countries is considerable, but the problems are con-continually changing and increasing.

It is therefore important for our aerodynamic laboratories to be provided with the necessary material and means for performing the immense task devolving upon them. It was, in fact, by increasing the efficiency of the experimental apparatus that the remarkable properties of modern wing sections were discovered. Perhaps by tomorrow these means will be insufficient.

It is important, especially for the present, to utilize to the fullest extent the experimental equipment of existing laboratories. This is simply a question of sufficient appropriations for paying the indispensable technical experimenters. An experimental investigation is not simply making more or less accurate weighings or measurements, but it necessitates a thorough study of the problem presented, of previous documents and of the causes of error, a judicial and critical analysis of the data obtained and the making of deductions therefrom. This work is of an order more intellectual than material and constitutes the reason why it should only be entrusted to competent intellects. Such a select personnel merits material recompense corresponding to the nature of its work.

In this connection, theoretical investigations are desirable and should even precede the experiments. It is remarkable that most of the good modern wing sections were designed by purely theoretical methods. The teaching of theoretical aerodynamics should be systematized in this respect, not simply because it constitutes a science of general culture (general motion of fluids), but also because such instruction will direct many of our future professors and scholars toward the technical problems of aerial locomotion.

Government appropriations and private donations to this work will constitute an investment of the first order, for science pays dividends in the form of discoveries whose far-reaching moral and financial effects are incalculable. Aerodynamics is no exception to this rule.

It would, moreover, be extremely dangerous for our future safety to fall behind certain other countries in this respect, which, unfortunately, is now the case. Nevertheless, we have in France, everything necessary for conducting these researches and, in certain respects, we even possess better experimental apparatus than any other country. Let us beware lest our failure, for the sake of economy, to provide for the appointment of a few additional engineers may cost us very dearly in the future.

Translated by the National Advisory Committee for Aeronautics.